MICRO-CHANNEL PLATE DETECTOR

CROSS REFERENCE TO RELATED PATENT APPLICATIONS

[0001] The present application claims priority to U.S. Provisional Patent Application No. 61/338,841 filed Feb. 24, 2010. The contents of this application are incorporated herein by reference in their entirety.

STATEMENT OF GOVERNMENT INTEREST

[0002] The United States Government claims certain rights in this invention pursuant to Contract No. DE-AC02-06CH11357 between the U.S. Department of Energy and UChicago Argonne, LLC, representing Argonne National Laboratory.

FIELD OF THE INVENTION

[0003] The present invention relates generally to micro-channel plate (MCP) detectors. More particularly the invention relates to an MCP detector for radiation detection and signal amplification fabricated from an anodized aluminum oxide (AAO) membrane containing nanopores in a range of diameters which have been coated with an atomic layer deposition (ALD) process.

BACKGROUND

[0004] A Micro-Channel Plate (MCP) is an array of miniaturized electron multipliers oriented substantially parallel to each other and either parallel or at a bias angle up to about 19° to the plate normal. An MCP typically consists of lead silicate glass and is designed for radiation detection and signal amplification applications. The micro-channels are coated with various chemicals to enhance secondary emission and to improve detection efficiency for a specific source, e.g., UV, soft x-ray, etc. Commercial devices are fabricated with channel diameters 25 microns and below, and the most advanced MCP is equipped with 2 micron channels for high image detail and fast response time. (see, for example MCPs from Burle Technologies, Inc.)

[0005] The fabrication of MCP's is generally a multi-step process that involves development of specialty glasses for core and clad, communication fiber glass drawing, assembly into hexagonal array, fusion into a boule, and wafer slicing and processing. The fabrication cost of these processes is very high, large area MCPs are difficult to produce, and the technology to go beyond the sub-micron limit has not been demonstrated.

[0006] Anodized aluminum oxide (AAO) has attracted significant interest among the nano-science and engineering research community in recent years. AAO consists of highly aligned nanopores "self-assembled" in a hexagonally close-packed pattern. The pore diameter and pore-to-pore distance range between ~10 to 300 nm and from 30 nm to submicron, respectively. These nanopores can be prepared in a simple wet chemistry lab without complicated equipment. The nanopore diameter and pore distance can be well controlled through anodization parameters as well as postanodization chemical etching. These nanopores are highly ordered within a domain but do not exhibit intrinsic long range order. Nanopores can be filled using electrodeposition to prepare metallic (Cu, Ag, Au, etc.) or ferromagnetic nanowires (Fe, Co, Ni, etc.). These nanoscaled objects have been studied for their magnetic anisotropic behavior and complex multi-segmented nanow-ires have also been developed. The multi-segmented design may be used to enhance self-assembly of these materials.

[0007] Together with chemical vapor deposition (CVD) and atomic layer deposition (ALD), semiconductive nanowires and nanotubes such as ZnO, CdS, CdSe, GaAs, etc., have been synthesized for photonic devices, transistors, and biological sensing and detection applications using AAO membrane. The AAO membrane, when coated through ALD, has been developed into a new membrane catalyst. With precise reaction parameter control, chemical reactions such as dehydrogenation with high selectivity has been demonstrated. The AAO membrane when coated with ZnO was reported to be a high surface area dye-sensitized solar cell with reasonable power efficiency. With short anodization time, a nanowell structure can be prepared with shallow nanopores. These nanowells have been developed into hydrogen sensors with Pd nanoparticle decoration. In addition, these nanowells give rise to interference colors and the interference spectra are sensitive enough to pick up one monolayer of explosive molecules such as di- and tri-nitrotoluene. Due to the high aspect ratio (>1,000) in the AAO nanopores, the AAO membranes are reported to lead to highly anisotropic etching and are being developed into various MEMS (micro-electromechanical system) devices such as RF MEMS inductor, microcantilevers, capacitive MEMS humidity sensor, and various gas sensors, etc.

[0008] The chemical composition of the AAO film is primarily amorphous alumina (Al_2O_3). The chemical inertness and the mechanical hardness make the AAO thin films ideally suited for surface protection as well as metal finishing and decorative purposes. The free standing membranes with different pore sizes are also commonly used for filtration and separation in chemical and biotech labs. The chemical inertness also makes the AAO an ideal template for nanoscale synthesis. Most applications do not require long range order in the pore arrays. However, long range order can be established with use of more sophisticated and expensive methods such as photo- and e-beam lithography, as well as focused ion beam (FIB). With long range order in the nanopore arrays, more advanced development in electronic and magnetic devices as well as photonic applications are expected in the future.

[0009] The formation mechanism of AAO membranes was first proposed in the early 1950s. Key elements of AAO membranes consist of straight nanopores with a spherical bottom less than a hemisphere. The contour of the cell base pattern can be described with a center of curvature and a radius of curvature. The earlier model was expanded significantly in the 1970s. The revised model is shown in FIG. 1. The center of curvature (A) is continuously moving downward during anodization. The active layer during nanopore growth is the bottom barrier layer with thickness (d). There are two active interfaces on the barrier layer. The outer one is associated with anodization of aluminum to alumina, and the inner one associated with dissolution and deposition of alumina to and from the etching solution. The process is driven by the local electric field (E) which is defined by the applied current (I) over conductivity (σ) times the surface area of the spherical bottom $(\omega/4\pi) \times 4\pi b^2 = \omega b^2$ where ω is the solid angle and b radius of curvature.

[0010] Under a constant applied current (or potential E) and during equilibrium growth, each nanopore reaches an optimized solid angle ω and radius of curvature b. Each nanopore slowly moves its position with respect to its closest neighbors